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# Use of Humanoid Robot in Children with Cerebral Palsy: The Ups and Downs in Clinical Experience

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**Abstract**

Cerebral palsy (CP) is a disorder that impairs motor function in children resulting in limitation to execute active daily life. It is caused by the non-progressive insult to the immature brain. The common features of children with CP are spasticity, muscle weakness, balance and poor motor function. CP may also affect cognitive function. Recently, the technology of rehabilitation robotic has gained great interest in the research field for disabled children. The humanoid robot is one type of the Socially Assistive Robotic (SAR) that has the potential to be used in rehabilitation for children with CP. This study gave repetitive exposure to two children with CP through the humanoid robot NAO in four interactive scenarios for once a week over a period of eight weeks. This work is expected to examine how the human-robot interaction (HRI) impacts the attention and gross motor function. This paper aims to describe the clinical experiences and challenges using the humanoid robot for therapy in children with CP.

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*Keywords:* clinical experience; cerebral palsy; humanoid robot; human-robot interaction; rehabilitation robotic

## 1. Introduction

The work described in this article is a form of Robot-Based Intervention Therapy for Children with Cerebral Palsy (CP), which explores the potential use of the humanoid robot in clinical setting. This article presents clinical challenges and experiences throughout the process of repetitive exposure of children with CP towards the humanoid robot.

### *1.1. Cerebral Palsy*

CP is the most common childhood motor disability that impairs movement and posture in children, posing significant limitations in their daily functional activities[1]. The incidence of CP in developed countries is 2-2.5 per 1000 live births[2,3]. The term CP covers a group of non-progressive, but often changing motor impairment syndromes secondary to lesions of the brain arising in the early stages of development[4]. The vulnerable brain is harmed during a critical period of development[2]. The damage

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usually occurs in the region of the brain that controls muscle function. Therefore, children with CP usually have problems with motor skills, abnormal muscle tone, muscle weakness, reflexes, coordination, and balance[4]. In addition, CP may also be associated with clinical manifestations and complications such as cognitive impairment, epilepsy, feeding, nutrition and growth problems, bladder dysfunction, bowel dysfunction, sleep disturbances, drooling, hearing loss, visual abnormalities, and orthopedic abnormalities that challenges clinical intervention[2].

Types of CP can be classified based on the neuromuscular deficits and patterns of movement that include ataxic, dyskinetic, hypotonic, spastic, or combination of these forms[5,6]. Spastic is the most observed pattern among these children[6]. The Gross Motor Function Classification System (GMFMCS) is a universal classification system that has been found to be a reliable, valid and applicable system that classifies children with CP by their age-specific gross motor activity[6]. It consists of five levels (level I-level V) which indicate different levels of physical limitation[6]. GMFCS helps determine the surgeries, treatments, therapies and assistive technology which result in the best outcome for the child. Currently, the field of robotic rehabilitation develop systems that assist persons with disabilities such as CP, autism, and the elderly to provide therapy in improving physical and cognitive function[7].

### *1.2. Emergence of Socially Assistive Robotic in rehabilitation*

The use of assistive technology has created new potential direction towards approaches and intervention available in CP rehabilitation. Socially Assistive Robotic (SAR) is an example of advanced technology that has a high capability to give assistance to human users, specifically in social interaction[8]. At present, research in SAR mostly has been applied in children with autism, dementia, stroke and the elderly[7,8]. Interest in SAR is broadening as one of the upcoming fields in next robotic generation, especially as assistive tools in rehabilitation. The assistive robotic has two forms that are humanoid and non-humanoid. The humanoid robot presented with physically shaped like a human being while non-humanoid robot usually in the form of machine or toy[7].

### *1.3. Humanoid robot NAO*

Nowadays, there are many interactive types of rehabilitation robotic tools are being developed and implemented. One of it is the humanoid robot who gains greater interest in rehabilitation setting. Most of the children interested in technologies like computer games, gadgets, and robots[9]. Thus, humanoid robot NAO (Fig 1) has the potential to be used as a tool in rehabilitation therapy for children with CP to acquire motor skills[10]. It can produce a controlled and repeatable movement[11]. The simple humanoid robot size is like a two years old toddler that can appeal the children to engage throughout the session.

Fig.1. Humanoid robot NAO

NAO is a 57cm high humanoid robot with 25 degree of freedom (DOF) that is commercially available and is produced by Aldebaran Robotic, a French company in 2008[12]. Features of humanoid robot NAO includes position sensors at each joint, two loudspeakers located at its head which act as its output devices, sonars on the body, voice recognition, swappable head and bumpers on the feet to detect collision with obstacles when it walks [12]. For this study, NAO will execute modules that focus on repetitive movements to improve truncal balance, coordination, and lower limb gross function of children with CP.

### *1.4. Human-Robot Interaction (HRI)*

Human-Robot Interaction (HRI) is a dynamic interaction between humans and intelligent robots[9]. It has expanded its role in clinical setting to assist disabled children. Statistically, researchers and practitioners who are the expert in HRI comes from a variety of fields that consist of engineering and also social sciences. One of the advantages of HRI is the experience of controllable and repeatable therapy[7,11].

Humanoid robot permits human-like gestures and direct imitation movement while non-humanoid robot involves computer and mechanical object. It assumes that HRI can provide a better experience for children with CP to develop motor skills precisely[10]. The humanoid robot with HRI architecture has high potential to facilitate motor development and to augment motor skills by repetitive exercising[11].

## 2. Challenges

The study has been conducted at the Medical Specialist Centre, Discipline of Rehabilitation Medicine, Faculty of Medicine, Universiti Teknologi MARA (UiTM) Sungai Buloh, Selangor, Malaysia. Ethical approval for this study was obtained from the Research Ethic Committee UiTM. The child has been exposed to humanoid robot NAO for once a week in eight consecutive weeks that consist of four interactive scenarios for each session. Each child was also provided with regular conventional treatment by a therapist for every session prior to the HRI. The combinations of conventional treatment with HRI are to ensure that the child can adapt with the new intervention using the humanoid robot. The adaptation process is crucial to evocate cooperation from the child. The research team in this study consists of multidisciplinary professionals who are expert health professionals and engineers.

### *2.1. Recruitment of the child*

The recruitment in this study must fulfill all these inclusion criteria; children diagnosed with CP (GMFCS level I- level IV), age group 5-14 years old, no hearing and vision deficit, able to follow simple command in English and parental consent. Two children were selected according to the inclusion criteria above. Table 1 below presents the demographic characteristics of the children included in the study.

Pre and post assessments were conducted for each child to evaluate the outcome on the completion of the HRI sessions. These assessments consist of Gross Motor Function Measure (GMFM), Time Up and Go (TUG) Test, Trail Making Test (TMT), and Intelligent Quotient (IQ) test. Each of assessment required different professional to assess the child. Diagnosis of CP was confirmed by a rehabilitation physician. Physiotherapist were responsible to evaluate the physical part (GMFM and TUG), while occupational therapist assessed attention capacity (TUG), and developmental psychologist assessed IQ level for the child.

Table 1. Demographic characteristics

| Basic Demographic | Child 1 | Child 2 |
|---|---|---|
| Age | 9 | 13 |
| Gender | Male | Male |
| Type of CP | Spastic hemi | Dystonic |
| GMFCS | Level II | Level IV |
| IQ Level | Below average | Below average |

### *2.2. Process of execution during experimental study*

Four interactive scenarios included in the study are presented in Table 2. The general aims of these interactive scenarios are to improve truncal balance, coordination, and gross motor function focusing on the lower extremity.

Table 2. Interactive scenarios

| Interactive Scenario | Description |
|---|---|
| Interactive scenario 1 | Introductory rapport |
| Interactive scenario 2 | Sit to stand |
| Interactive scenario 3 | Balance |
| Interactive scenario 4 | Ball kicking |

Interactive scenario 1 emphasizes on interaction and creates rapport between humanoid robot NAO and the child. It encourages the child to communicate with the robot. Both children looked forward and were enthusiastic to talk with humanoid robot NAO. As this scenario aim to create rapport with the humanoid robot NAO, the challenges appeared as the child had difficulties understanding the dialogue from humanoid robot NAO and required assistance from the therapist. As a result, positive triadic interaction developed between robot, child, and therapist. As the sessions proceed, the children can converse well with humanoid robot NAO and showed good responses. Another challenge faced was the difficulty in understanding the child's speech due to speech impediment. However, the therapist managed to encounter the challenges effectively by seeking clarification from parents and assisting response to humanoid robot NAO. The expected outcome of this module is to improve the child's adaptability to the social life especially in school because children with CP tend to have low self-concept[13] due to disorders.

Fig.2. Imitation learning sit-to-stand during HRI

Interactive scenario 2 encourages imitation learning for the child. They are required to follow the movement from sit to stand, imitating the humanoid robot NAO (Fig. 2). In this experimental layout, a mirror was placed in front of the child to guide them to do the movement with using correct posture. However, the therapist still needs to guide the child in term of body posture as they replicate the actual movement of humanoid robot NAO. To be precise, humanoid robot NAO portrayed incorrect body posture during sit to stand with excessive forward bending. The assistance from the therapist was needed to prevent incorrect imitation from the child. The kinematic of sit to stand that was performed by humanoid robot NAO, though, does not follow the typical movement by the human. It is due to the limitation in the DOF of humanoid robot NAO. Another challenge observed was the child had the tendency to loose focus especially for Child 1 after a few sessions. It is because the task in this scenario was not challenging for him as he has minor physical limitation (i.e. GMFCS Level II). Nevertheless, willingness of the child to comply and complete the scenario was observed.

Interactive scenario 3 aims to improve the balance of lower limb for the child. In this module, humanoid robot NAO will lift one leg alternately at one time for 10 seconds and the child requires to imitate the movement. Child 2 has a major physical disability, the ability to lift up one leg and balanced his body was more challenging, while Child 1 has abnormal left foot posture that interrupted his balance while lifting his right foot. The therapist had to give full attention and took precaution measures for both children by assisting them to complete this module and to prevent them from fall. This interactive scenario also needs assistance from therapist to ensure safety and provide coherent commands to the child regarding which leg should be lifted. Even though humanoid robot NAO gave the instruction to lift the specific leg, the child imitates the mirror image. Despite the module being complex and challenging, the child still complied and completed the session.

Finally, interactive scenario 4 is an activity to enhance lower limb function. During this activity, both children enjoyed kicking a ball with humanoid robot NAO. Taking turn kicking the ball with the robot was introduced in this module. Based on the observation, it showed both children have potential in socializing with their peers regardless of their physical limitation. Nevertheless, this scenario was challenging to the therapist as she had to focus and set up both robot and the child, and to give cues in this interactive scenario.

Interactive scenarios two to four also involved encouraging praises given by humanoid robot NAO once the child completed the tasks. It also gave encouraging phrases to motivate the child throughout the interactive scenario. Both children responded favorably to this approach.

## 3. Discussion

The implementation of the SAR in rehabilitation for children with CP is a new intervention that is still in its infancy stage. There are multiple potential uses for humanoid robots in clinical setting, especially its capability to encourage social interaction, motivation and imitation learning in rehabilitation. Additionally, the repeated exposure of the humanoid robot with children with CP allowed the children to spend their time to explore the triadic interaction space between robot-human and human-human interaction. Triadic interactions involved in this study may be challenging especially for children with speech impediment. The tendency for the humanoid robot to misinterpret children with the speech impediment is an identified problem. Even so, both children showed great interest during interaction with humanoid robot NAO. Table 3 shows robot based intervention study using humanoid robot for children with CP. The finding from these studies show good potential in using humanoid robots in rehabilitation for children with CP which can be seen in both children during this study.

Table 3. Study comparison using humanoid robot for children with cerebral palsy

| Authors | Humanoid robot (Name) | Repetitive exposure | Children with CP | Outcome measure | Summary |
|---|---|---|---|---|---|
| Kozyavkin et al[14] | Yes (KineTron) | Yes | Yes | No | Children motivate and actively participate in rehabilitation activities |
| Fridin et al[15] | Yes (RAC CP Fun) | No | Yes | Yes | Children created positive interactions with the robot |

Based on previous study revealed that children with autism exhibit the social interaction skills during repeated exposure with the humanoid robot that include imitation, turn taking games, role switch, and initiated interaction with the robot[16]. Almost all of these basic social interaction skills were included in this study. However, the previous study is different as they allowed free play while this study has four interactive scenarios that must be completed by the child. These interactive scenarios are structured and manually controlled and does not encourage free play. Nevertheless, in this study Child 1 exhibited free play that was unpredictable for humanoid robot NAO to respond. In a positive perspective, it encouraged joint attention between the child and therapist.

Different levels of physical limitation between both children had produced different outcome during HRI in term of attention. The different responses from both children with different characteristics gave an idea regarding choosing the appropriate interactive scenario. Based on observation, Child 1 with less physical impairment was easily distracted during the session as compared with Child 2 who was more focused and compliant. This may be due to the exposure of the same module over the eight week period that may not be challenging and interesting enough for Child 1. Hence, module variety may help the children to engage and improve attention throughout the eight weeks session. However, the features of humanoid robot NAO with its DOF must be taken into consideration when creating appropriate movement for the children to imitate.

During imitation learning in HRI, the therapist must take precaution measures with scenario involving balance and ball kicking to prevent falls. Physical disability in children with CP will limit them to perform the movement, but assistance from therapist makes it possible for them to accomplish it. In these interactive scenarios, humanoid robot NAO will give cues for the child in each module for them to follow the movement. However, those cues from humanoid robot NAO are not sufficient and still require therapist's cues. Based on responses in both children, they easily understood the cues from the therapist compared to the robot. Similarly, the outcome of a study among children with autism revealed these children showed significantly fewer imitations of verbal behaviors with the robot than did those with the human[17]. Apart from that, encouragement and appraisal provided by humanoid robot NAO to the child as they completed the task ensured the child maintained engagement. Duquette et al.[18] conducted a similar study in which the robot also gave positive feedback on child performance resulted in increased shared attention and imitation of facial expression.

## 4. Conclusion

This research presented a study on the repetitive exposure of children with CP using the humanoid robot NAO. There are many potential advantages to using the humanoid robot for HRI in clinical setting for children with CP. The advantages include NAO's ability to produce controlled and repeatable movement which encourage imitation learning, socializing and motivate the children. Despite these good potential, research in this area requires further in-depth exploration. The challenges faced throughout the study gave a good reflection that could be used as guidelines to create better interactive scenarios with the aim of improving outcome for children with CP.

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